Evapotranspiration Cover For Containment At US Army Fort Carson Landfill Site

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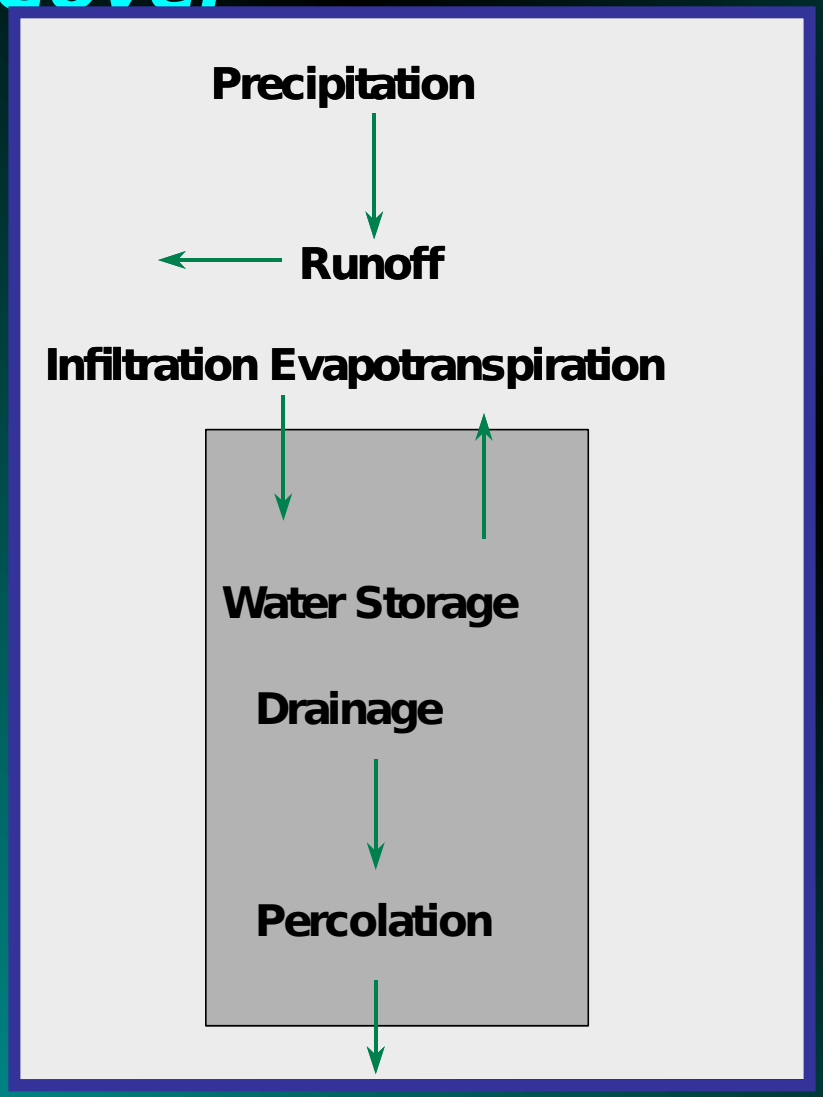
Overview

- Background Information
- Characterization of Borrow Soils
- Model Simulations and Final Design
- Construction
- Post-Construction Analysis
- Performance Monitoring

Evapotranspiration (ET) Landfill Cover



- ET Cover Is an Alternative to a RCRA Prescriptive Cover If Hydrologic Performance Is Equivalent
- An ET Cover Is Designed to Minimize Deep Drainage by Providing Sufficient Soil Water Storage During Wet Periods and Promoting Soil Water Loss Through Evapotranspiration
- Performance Elements
  - Climatic Conditions
  - Soil Water Retention
  - Cover Thickness
  - Plant Transpiration
- Cost to Design and Construct the 6 Ha (15 Acre) Fort Carson Et Cover Was $172,500 Per Ha ($70,000 Per Acre). RCRA Subtitle C Prescribed Cover Cost May Exceed $370,500 Per Ha ($150,000 Per Acre)

US Army Fort Carson ET Cover

- RCRA Subtitle C Landfill
- Permitted Through CDPHE
- Located in Colorado Springs, Colorado
- Annual Average Precipitation - 41 cm (16 in)
- Borrow Soil from Local Quarry
- 122 cm (48 in) Thick Monolithic Cover

Borrow Soil Characterization

- Description and Sampling Strategy Dependent on Depth and Variability (Excavated Pits, Cuts, Augured Cores)
- Fort Carson Borrow Originated from Loess Soil (Wind Blown) and therefore Relatively Uniform
- Soil Horizons Described in the Field and Sampled Following Evaluation of Descriptions
- Sample Analysis-Physical/Hydraulic
  - Rock Fragment/Particle Size Distribution
  - Soil Structure
  - Soil Water Retention Characteristics
  - Saturated Hydraulic Conductivity
  - Standard Proctor Tests
  - Atterberg Limits
- Sample Analysis-Chemical
  - pH
  - Electrical Conductance
  - Sodium Adsorption Ratio (Salinity)
  - Organic Matter

LYSIMETER WATER STORAGE TEST RESULTS

Process

- Lysimeter Packed With Clay Loam to 1.3 G cm $^{-3}$
- Lysimeter Dosed With 850 L (225 gal) Over 8 Days
- 170 L (45 gal) of Drainage
- Final Measurements Obtained 14 Days Following
  No Reported Drainage

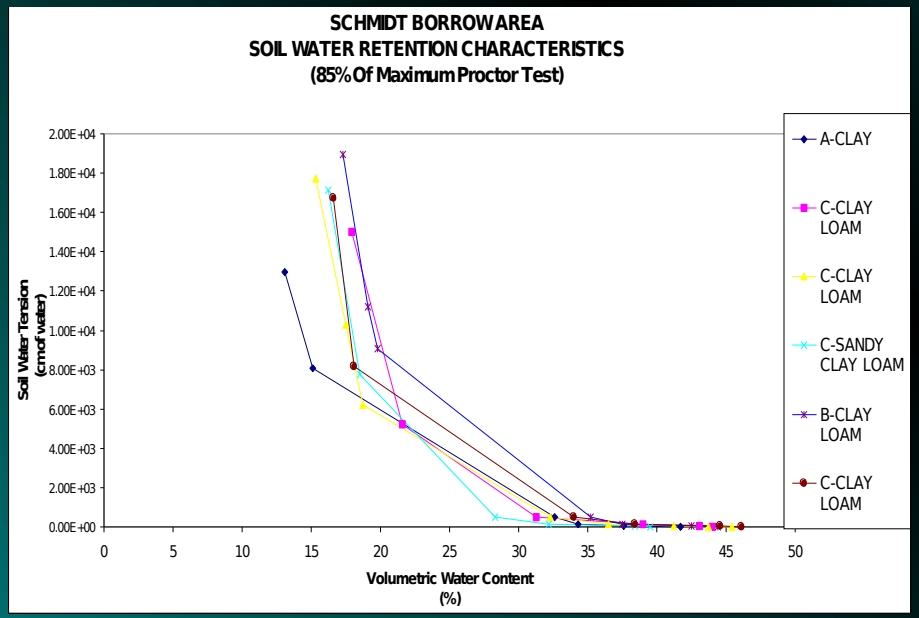
Results

Depth Interval in	Volumetric Soil Water Content[1] $in^3\ in^{-3}$	Water Storage in
0 - 12	0.33 (	3.96
12 - 18	0.34 (	2.04
18 - 24	0.35 (	2.10
24 - 30	0.36 (	2.16
30 - 36	0.38 (	2.28
36 - 42	0.39 (	2.34
42 - 48	0.39 (	2.34

Total = 17.2 in

Total water storage capacity assuming soil water content of 0.34 $in^3\ in^3$ =1

Fort Carson Evapotranspiration Cap Design-Water Balance Simulations



- UNSAT-H Model, 1-D Finite Difference Water Balance Model (Pacific Northwest National Lab)
- Four Year Simulation
- Wet Year =53 cm (21 in)
- Soil Hydraulic Characteristics of Borrow Soil Types
- Literature Based Native Grass Data
  - Bare Area = 50 %
  - Leaf Area Index = 0.5 to 1.5
  - 6.5 Month Growing Season
  - Root Depth to 122 cm (48 in)

EVAPOTRANSPIRATION CAPUNSAT-H MODELING RESULTS

Soil Horizon[2]	Soil Texture[2]	Physical & Hydraulic Properties	Predicted Annual Water Balance (cm)[1]				
			Precipitation	Infiltration	Evapotranspiration	Storage	Percolation
A	Clay	In-Situ	53.3	20.7	21.9	22.1	<0.01
B	Clay Loam	In-Situ	53.3	6.1	7.0	22.4	<0.01
B	Clay Loam	In-Situ	53.3	20.2	20.5	15.8	<0.01
C1	Clay Loam	In-Situ	53.3	38.8	39.2	23.4	0.01
A	Clay	75% Proctor	53.3	53.6	55.3	22.2	0.01
B	Clay Loam	75% Proctor	53.3	53.1	55.0	25.2	0.01
C1	Silt Loam	75% Proctor	53.3	52.8	53.9	22.5	0.02
C2	Clay Loam	75% Proctor	53.3	53.8	56.1	21.7	0.02
C3	Sandy Clay Loam	75% Proctor	53.3	53.1	54.4	21.2	0.02
A	Clay	85% Proctor	53.3	13.2	67.8	12.3	<0.01
B	Clay Loam	85% Proctor	53.3	6.4	7.8	15.9	<0.01
C1	Silt Loam	85% Proctor	53.3	12.4	13.9	15.1	<0.01
C2	Clay Loam	85% Proctor	53.3	25.5	26.9	16.9	<0.01
C3	Sandy Clay Loam	85% Proctor	53.3	13.8	15.2	13.8	<0.01

Design & Construction

- Construction Completed in August 2000
- ET Cover = 6 ha (15 acre)
- Monolithic Soil Cover (no membranes)

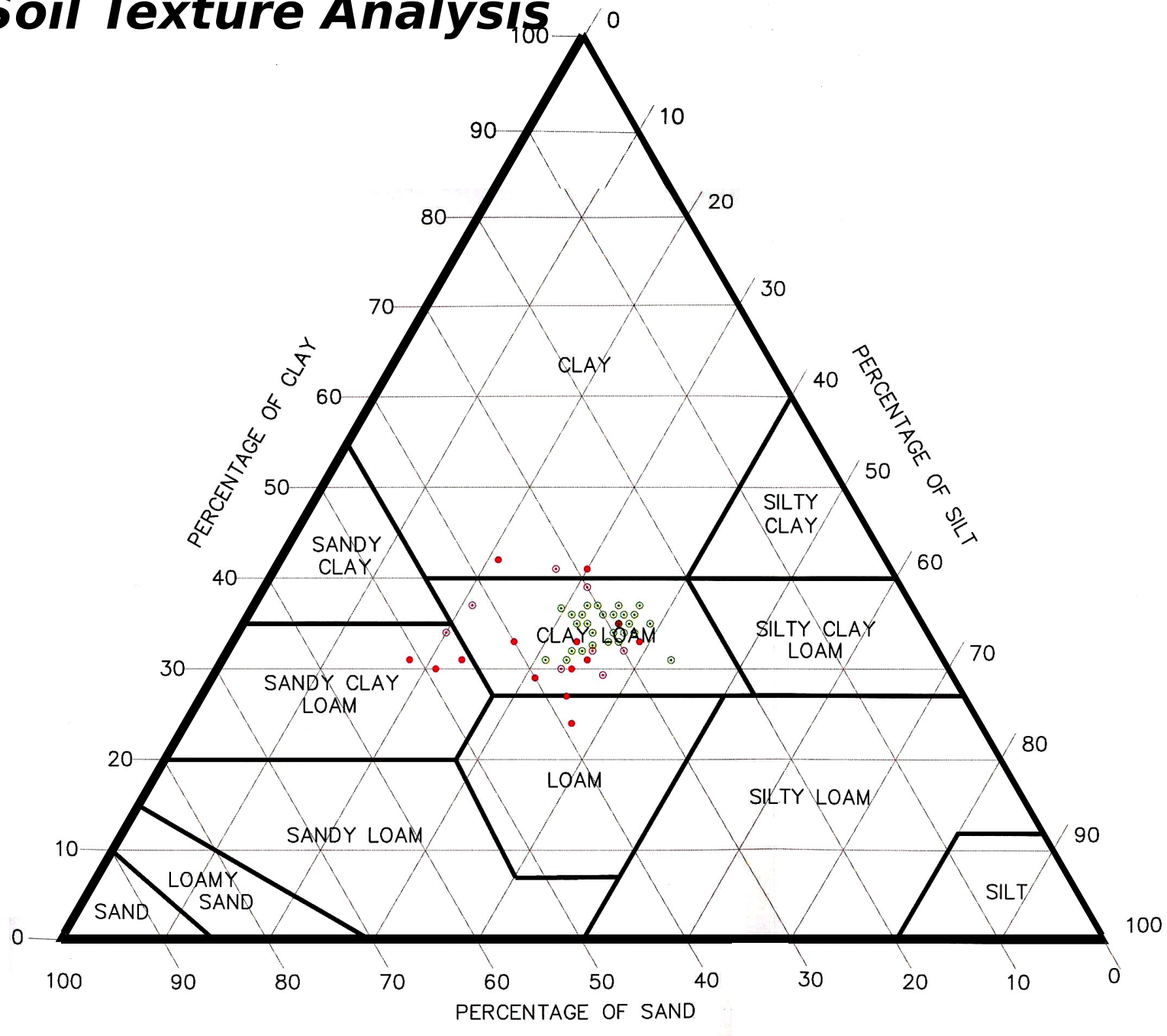
  122 cm (48 in) Thick CL (USCS) or Clay Loam (USDA)
- Four Construction Lifts, Each 30 cm (12 in)
- Compacted to 80 % to 90% of Maximum Dry Proctor Density
- Native Grass Vegetation (Cool & Warm Season)

  Western Wheatgrass
  Streambank Wheatgrass
  Alkalai Sacaton
  Galleta
  Blue Grama
  Sideoats Grama

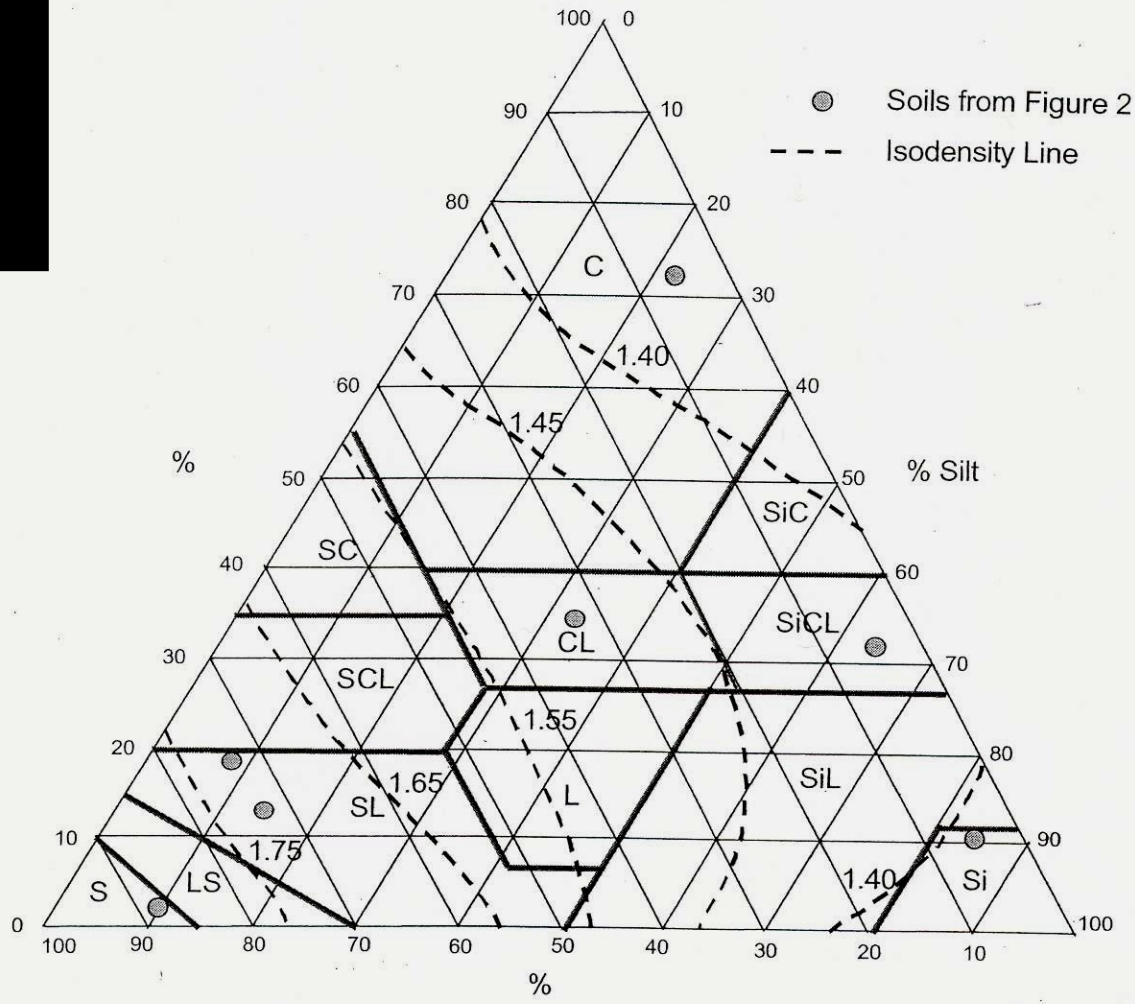
Post-Construction Analysis

- **Soil Texture Uniformity**
- **Dry Bulk Density**

Soil Texture Analysis



Growth Limiting Bulk Density

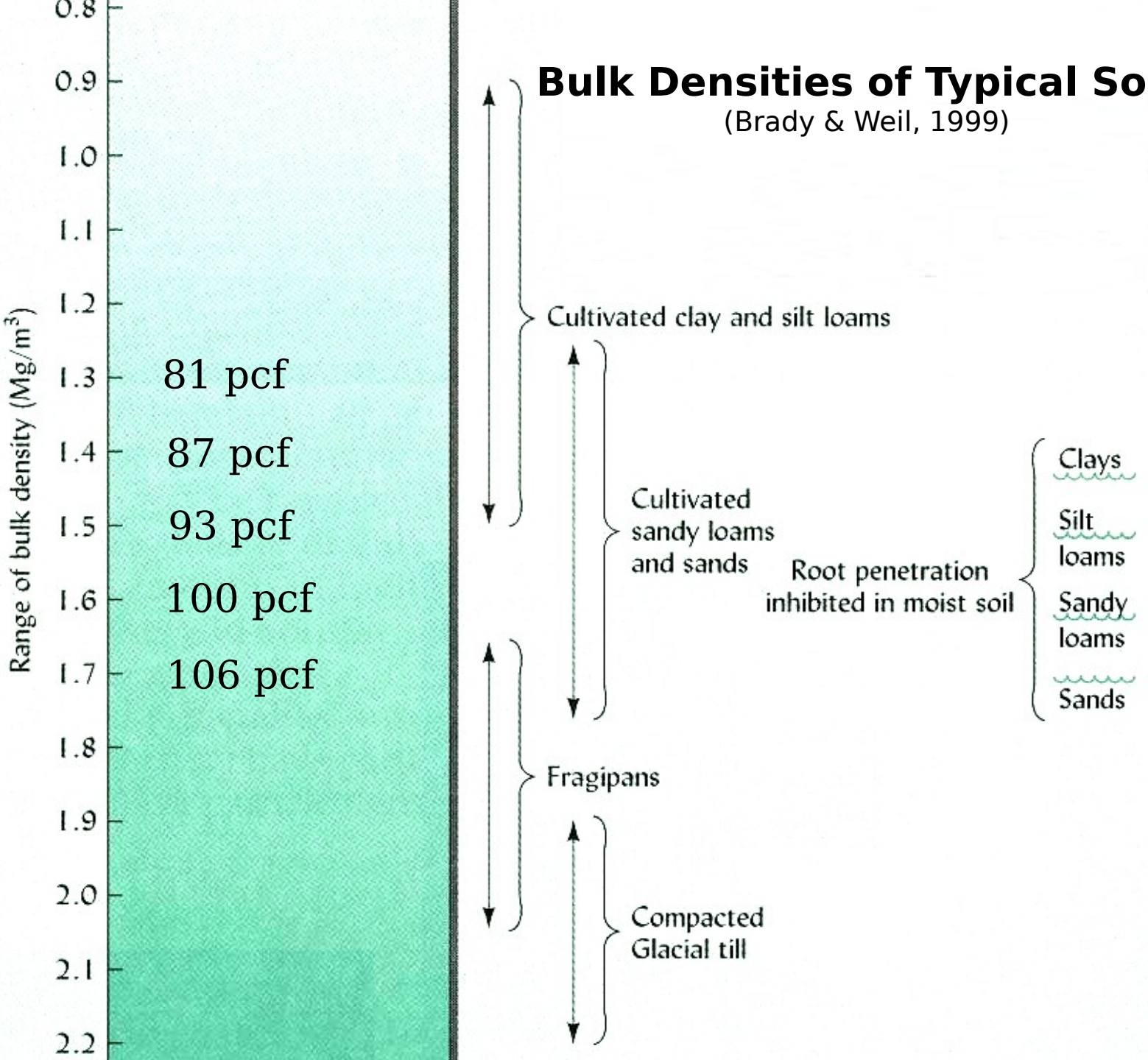


POST-CONSTRUCTION SOIL ANALYSIS RESULTS

Monitoring Location[1]	Depth m (in.)	USDA Soil Texture[2]	Bulk Density[3] Cylinder	Hydraulic Conductivity ($cm\ s^{-1}$)[4]
CL1	0.30 (12)	Clay	1.35 (84)	$2.7x10^{-4}$
	0.61 (24)	--	1.06 (66)	--
	0.91(36)	Clay	1.22 (76)	$6.4x10^{-4}$
	1.2 (48)	--	1.16 (72)	--
CL2	0.30 (12)	Clay	1.65 (103)	$4.6x10^{-5}$
	0.61 (24)	--	1.46 (91)	--
	0.91(36)	Clay	1.40 (87)	$1.0x10^{-3}$
	1.2 (48)	--	1.47 (92)	--
CL3	0.30 (12)	Clay	1.63 (101)	$6.0x10^{-3}$
	0.61 (24)	--	1.58 (98)	--
	0.91(36)	Clay	1.50 (93)	$3.6x10^{-4}$
	1.2 (48)	--	1.45 (90)	--
PS1	0.30 (12)	Clay Loam	--	--
	0.61 (24)	Clay Loam	1.53 (95)	--
	0.91(36)	Clay Loam	--	--
	1.2 (48)	Clay Loam	1.68 (105)	--
PS2	0.30 (12)	--	--	--
	0.61 (24)	Clay Loam	1.49 (93)	$1.7x10^{-4}$
	0.91(36)	--	--	--
	1.2 (48)	--	1.47 (92)	--
PS4	0.30 (12)	Clay Loam	1.42 (88)	--
	0.61 (24)	Clay Loam	1.43 (89)	--
	0.91(36)	Clay Loam	--	--
	1.2 (48)	Clay Loam	--	--
PS5	0.30 (12)	Clay	1.29 (80)	$2.4x10^{-4}$
	0.61 (24)	--	--	--
	0.91(36)	Clay Loam	1.49 (93)	$2.4x10^{-3}$
	1.2 (48)	--	--	--

Bulk Densities of Typical Soils

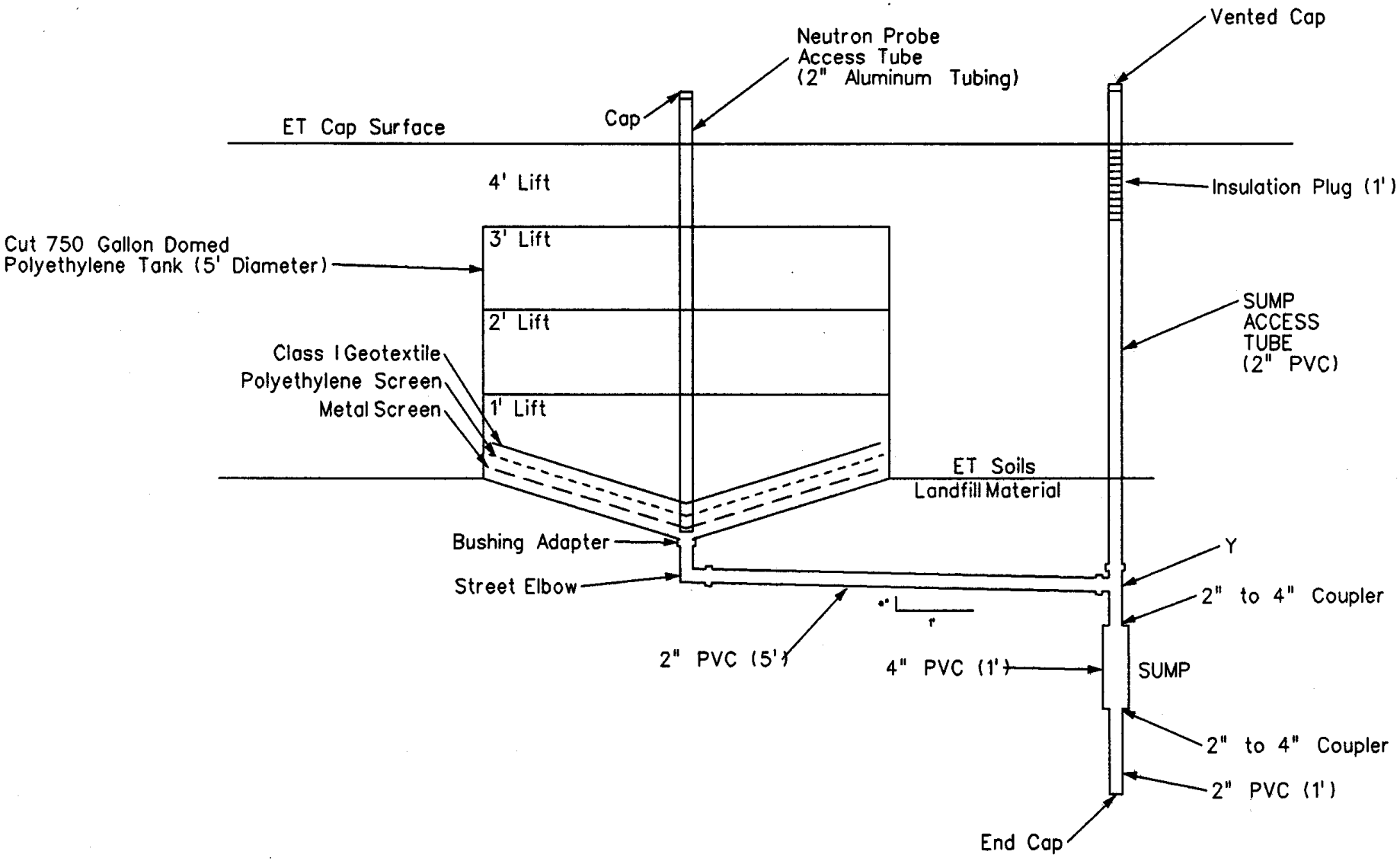
(Brady & Weil, 1999)



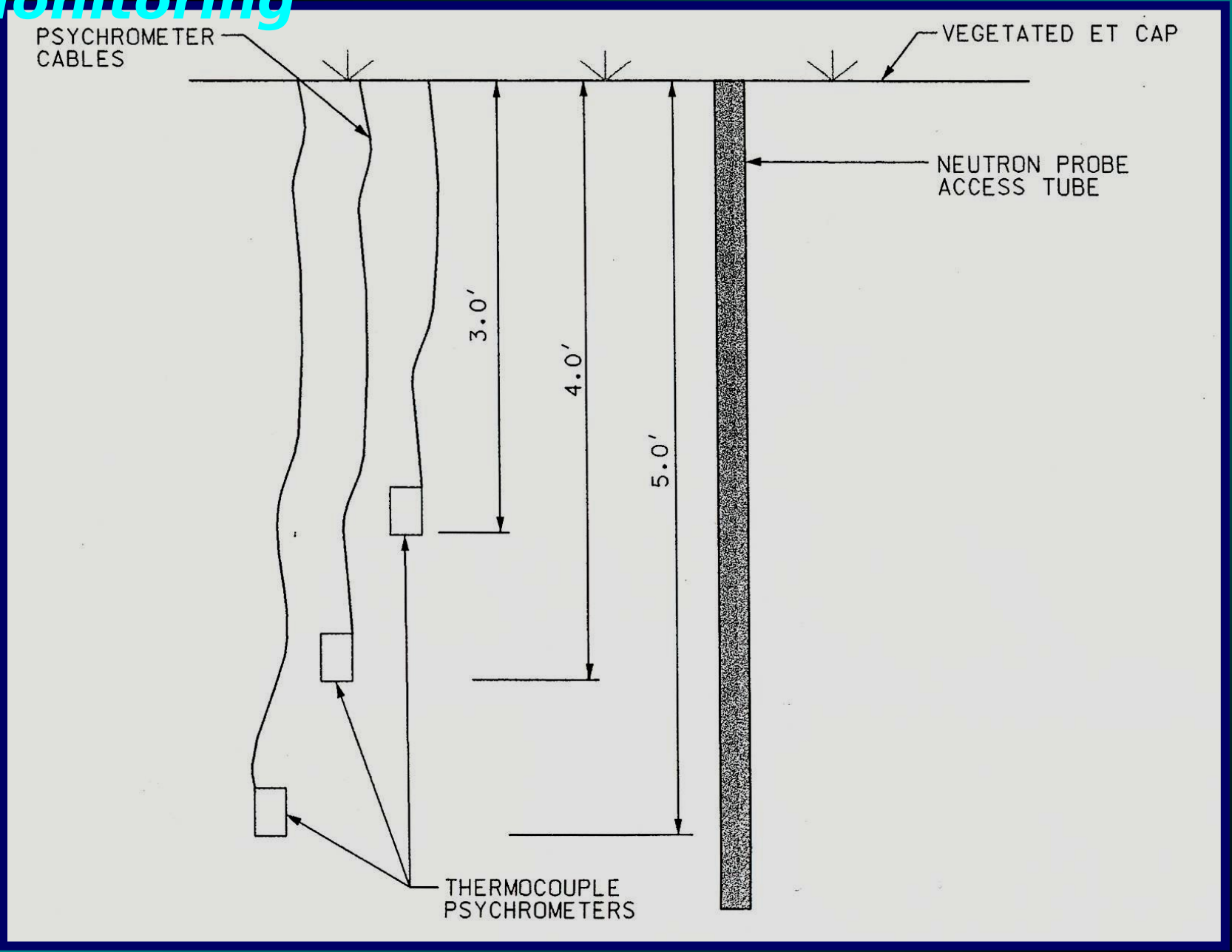
Hydrologic Performance Monitoring

- **Monthly Soil Water Monitoring Since September 2000**
- **Drainage Lysimeters (3 Locations)**
- **Soil Profile Water Content (8 Locations) – Portable Neutron Probe**
- **Vertical Hydraulic Soil Water Tensions (8 Locations)**

Field Lysimeter Construction



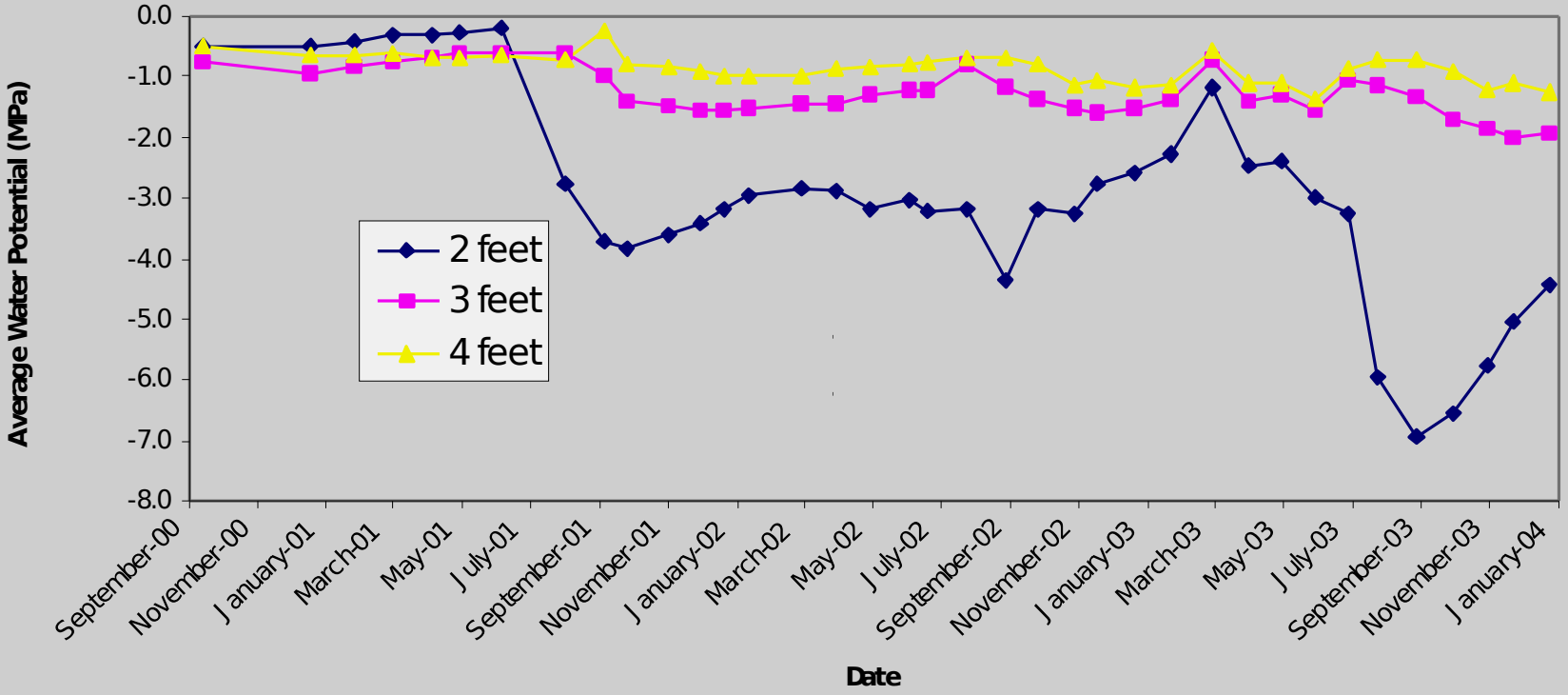
Psychrometer/Neutron Probe Monitoring



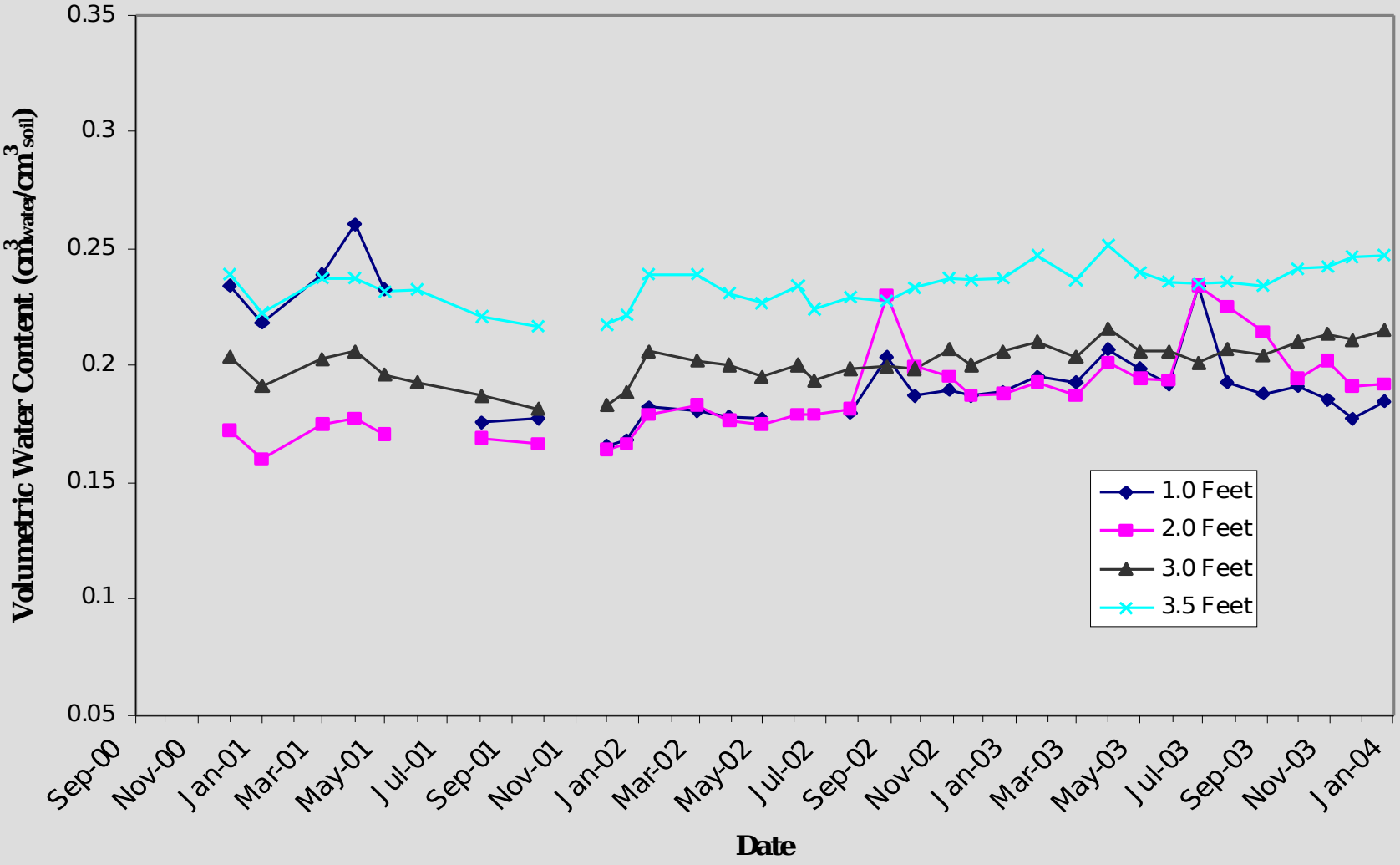
Monitoring Results

- Annual Lysimeter Drainage Typically Less Than 0.2 mm Per Year
- Highest Soil Water Storage = 30 cm (12 in) Compared to Water Storage Capacity of 43 cm (17 in)
- Water Content and Potential Data Indicate Frequent Periods of Upward Unsaturated Flow and Wicking of Water From the ET Cover Surface

Station PS2 Soil Water Tension



Station PS2 Soil Water Content



Summary

- Research and Demonstration Studies Suggest that Hydrologic Performance of Properly Designed ET Covers in Arid and Semi-arid Climates are Equivalent to Prescribed Covers
- Cost for Design and Construction of ET Covers May Be Significantly Less Than the Cost for Prescribed Covers
- Regulatory Agencies are Gradually Accepting Alternative Cover Technology